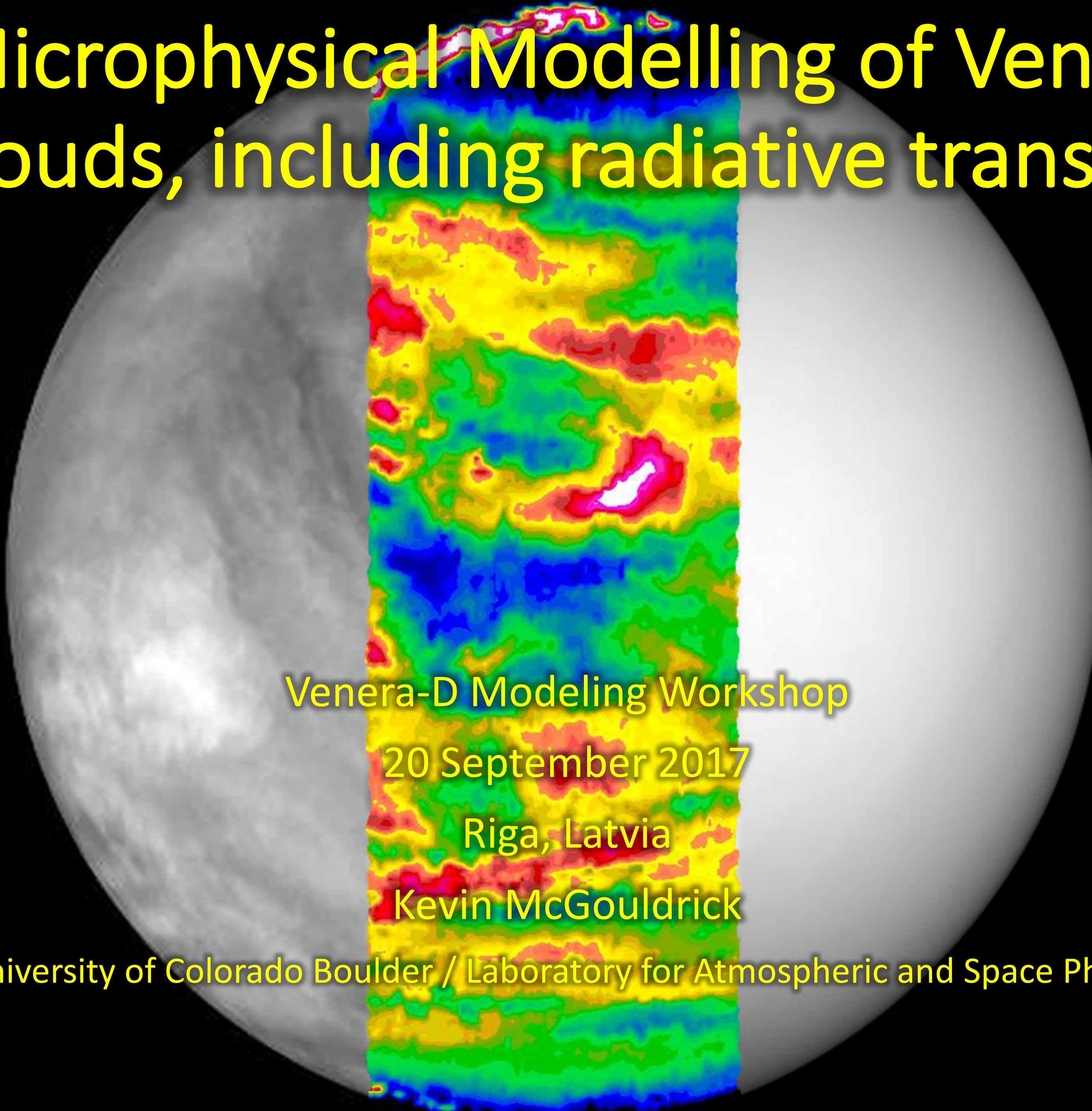
Microphysical Modelling of Venus Clouds, including radiative transfer



Venera-D Modeling Workshop

20 September 2017

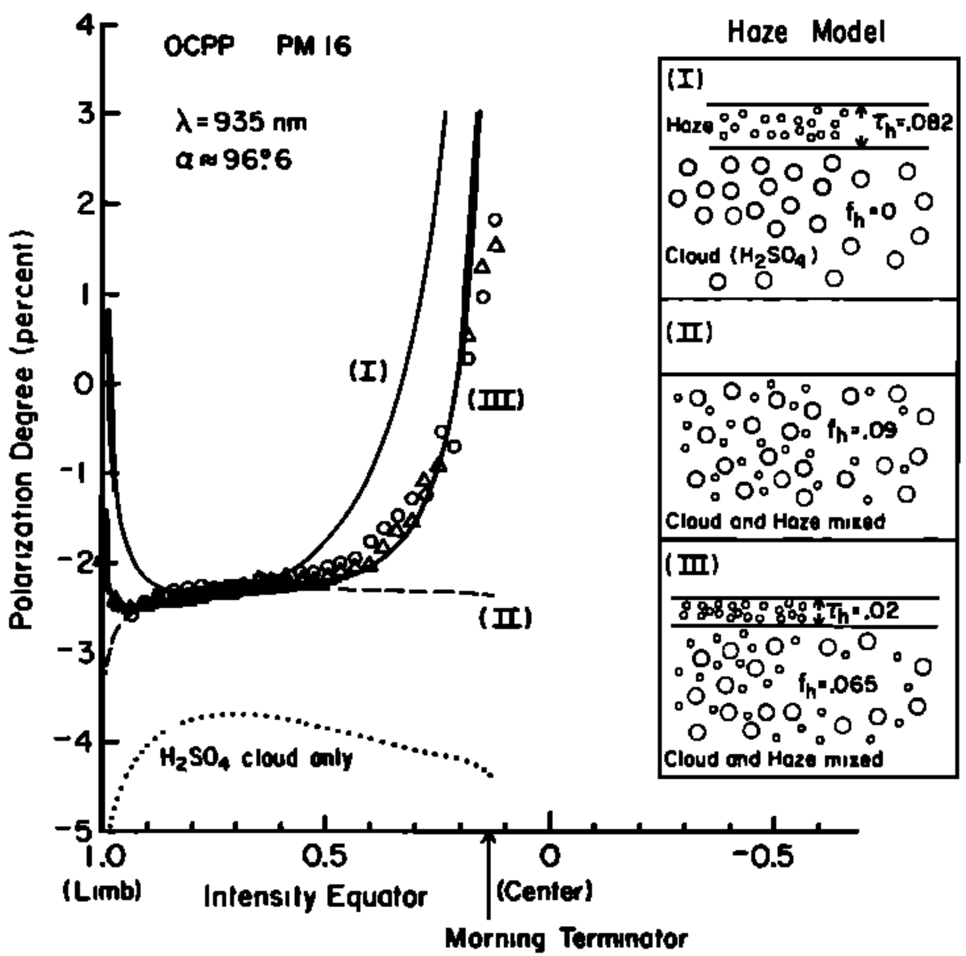
Riga, Latvia

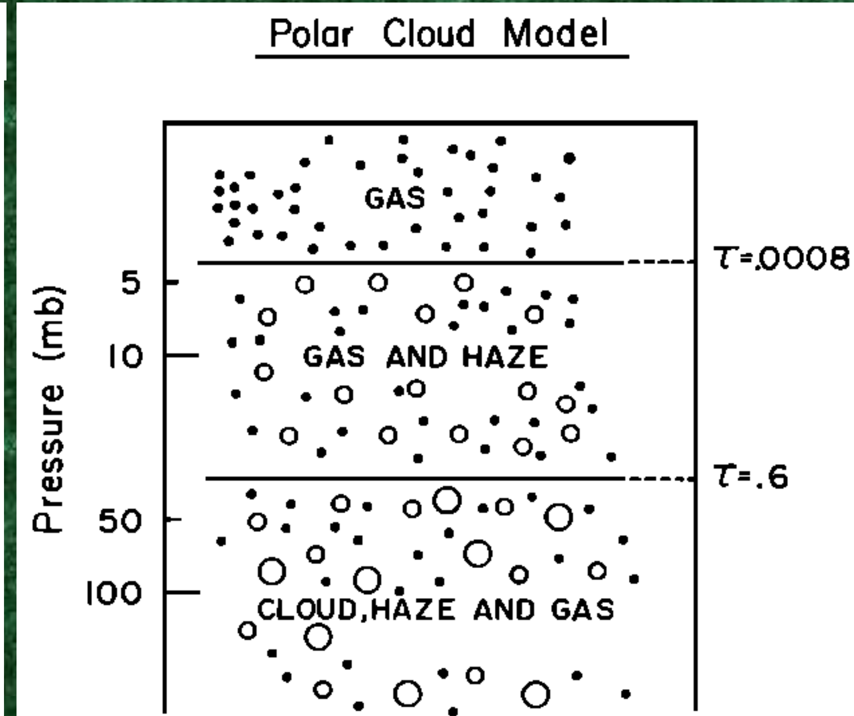
Kevin McGouldrick

University of Colorado Boulder / Laboratory for Atmospheric and Space Physics

Kawabata et al 1980 Polarimetry

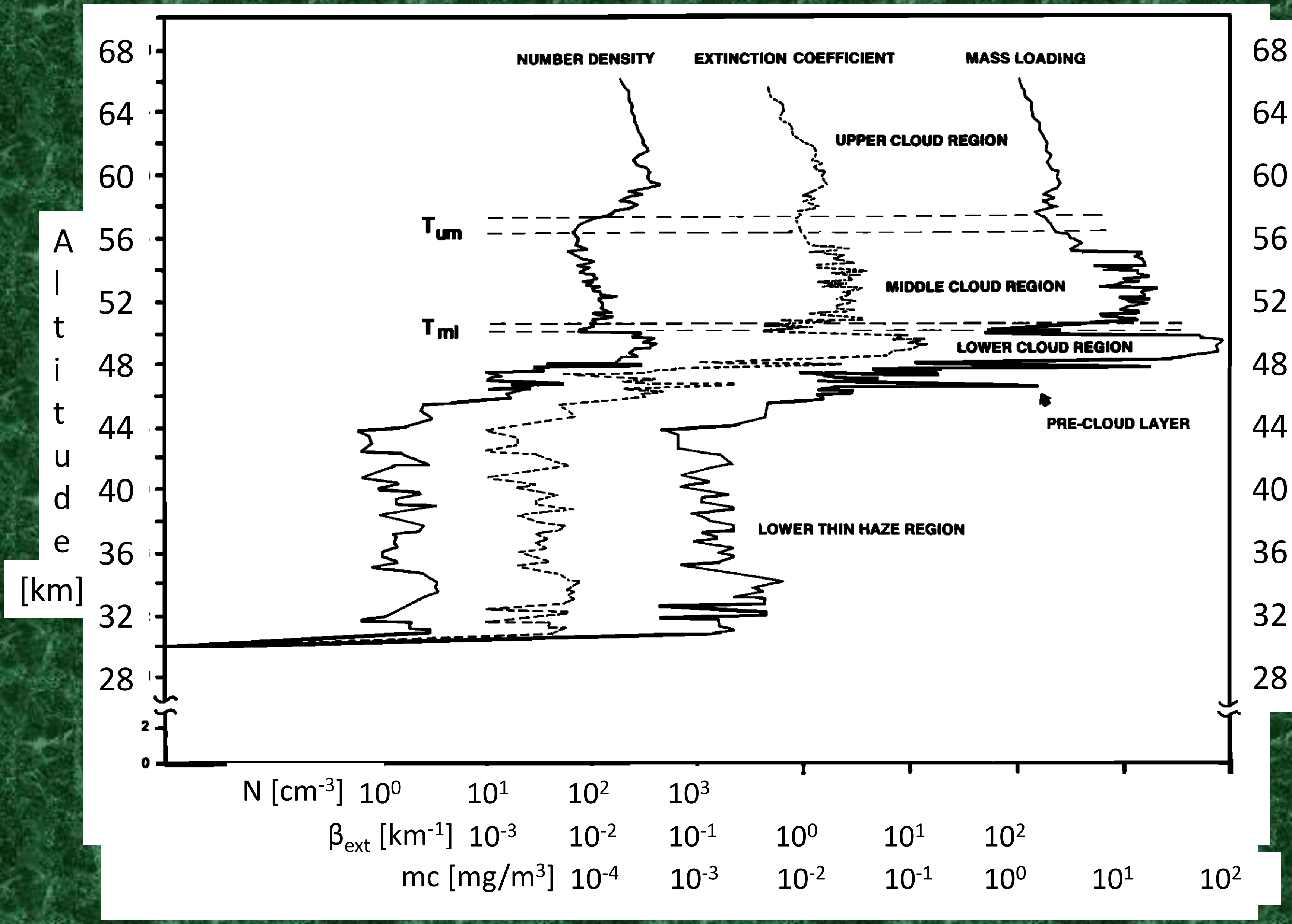
Equatorial Cloud Model(s)



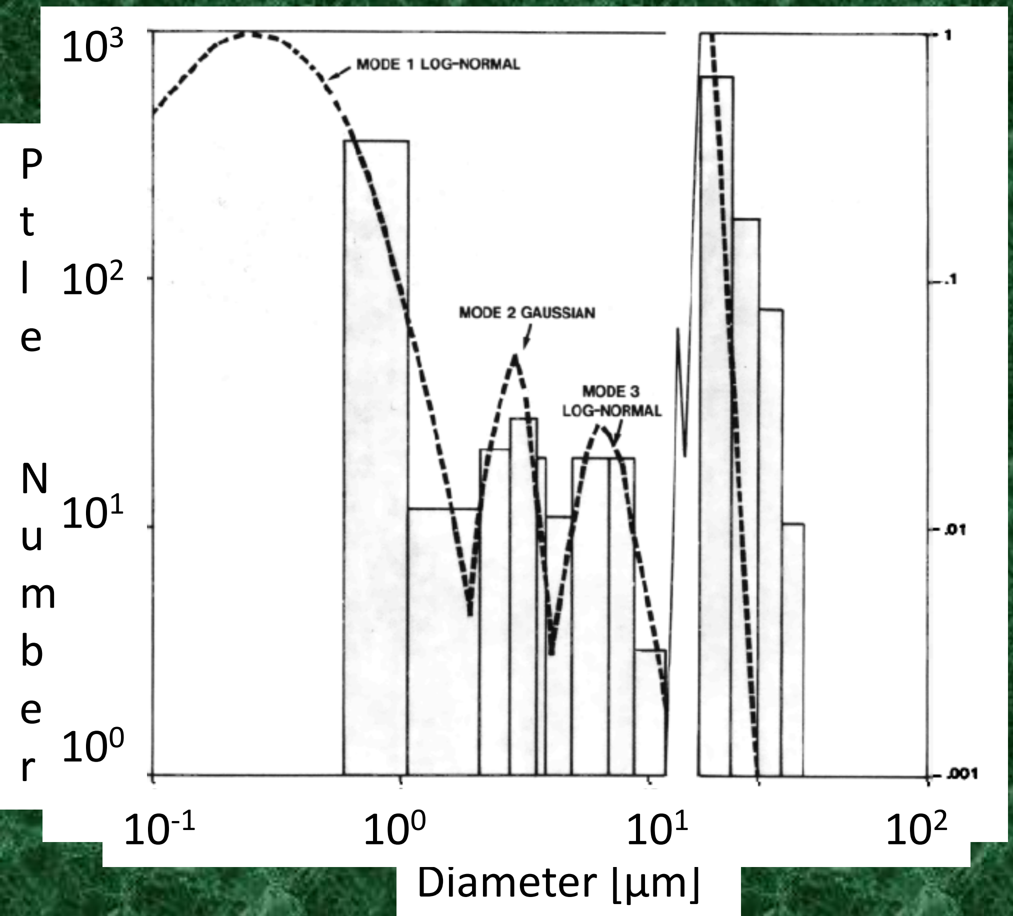


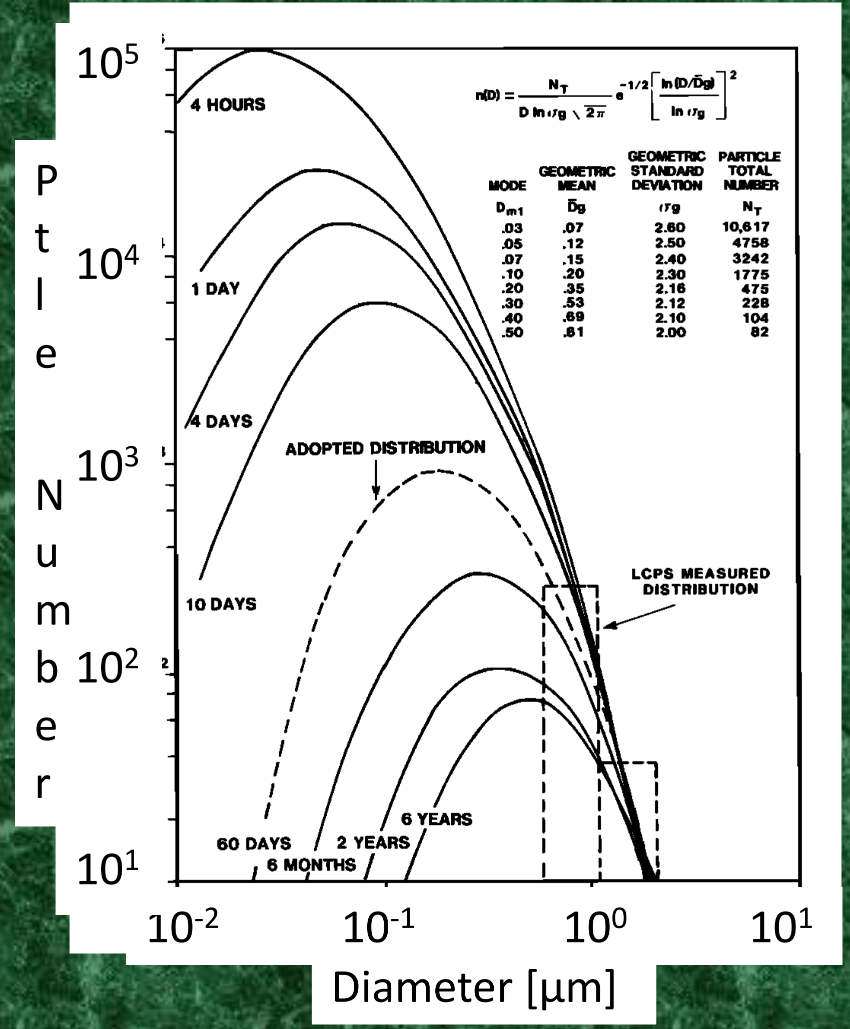
- Finds bimodal in most cases.
- Both consistent with H_2SO_4
- But, then, why bimodal?

Vertical Cloud Structure from LCPS



Size Distributions



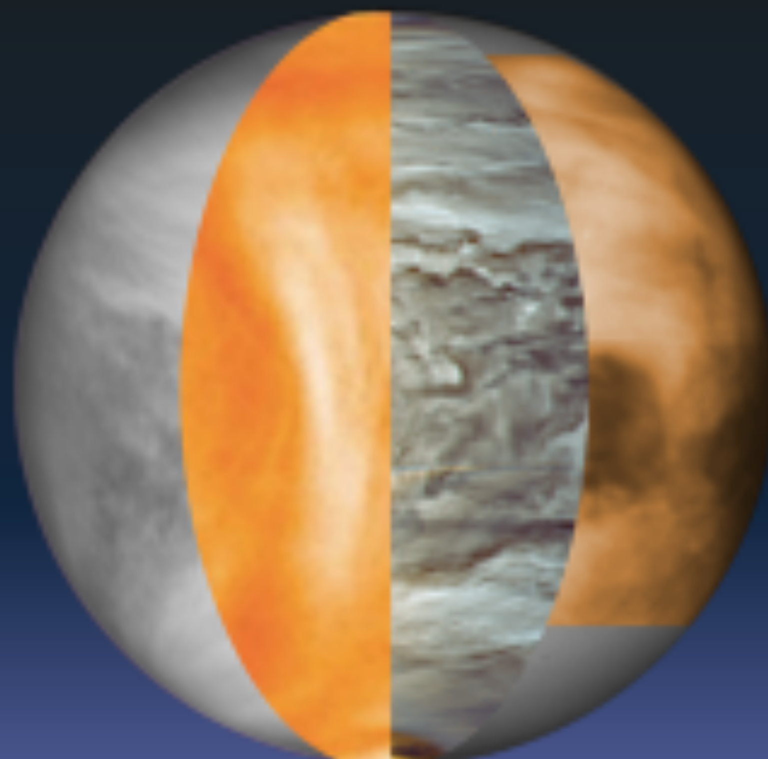


- Three size modes; but some ambiguity remains.
- Mode 1 peak unconstrained; based on assumptions regarding coagulation rate
- Mode 3 poorly fit; others (Toon et al 1984) suggested possible miscalibration.

The 74th Fujihara Seminar: "Akatsuki" Novel Development of Venus Science

International Venus Conference 2018

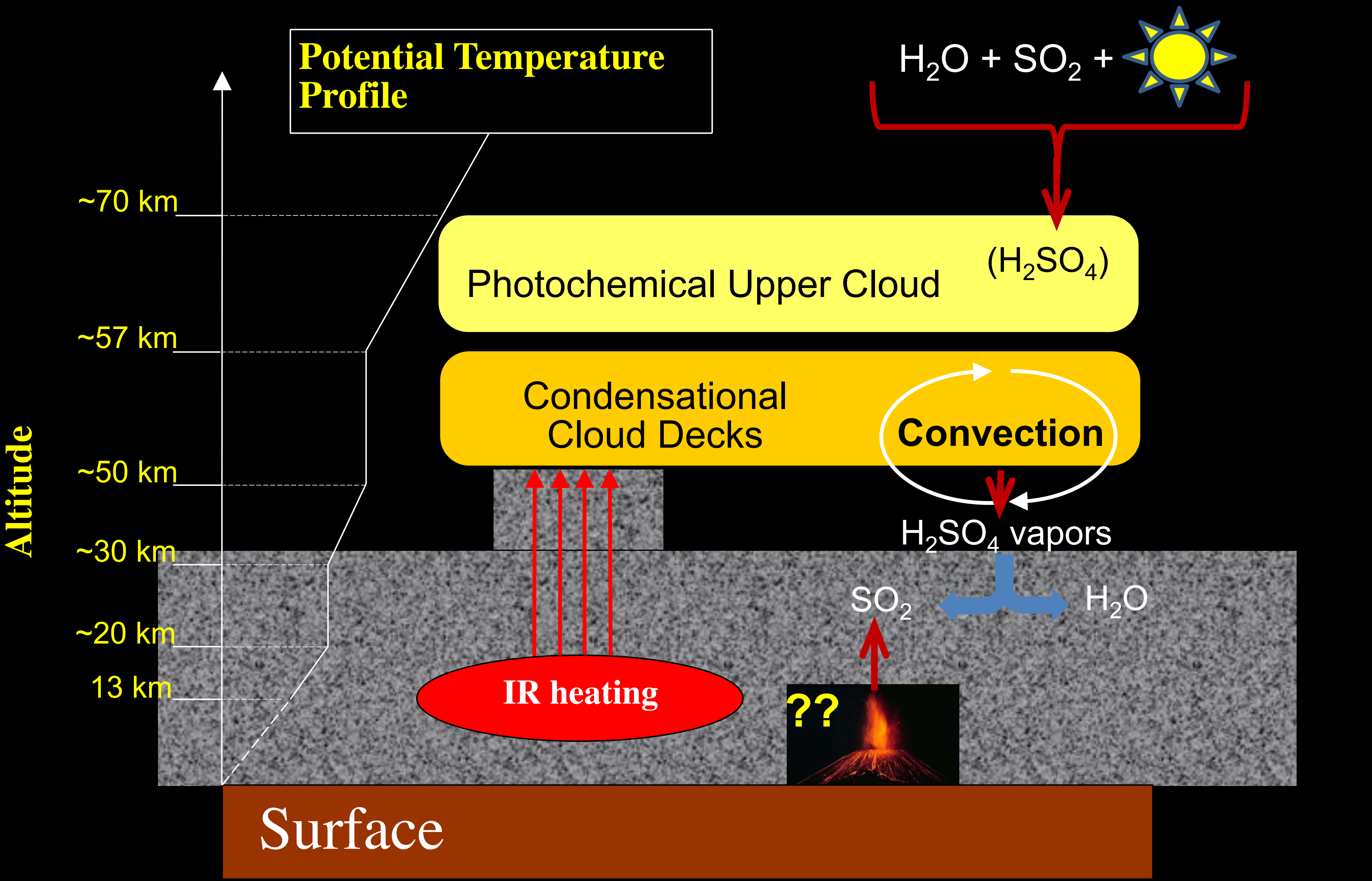
Date: September 11-14, 2018 / Venue: Hilton Niseko Village, Hokkaido, Japan



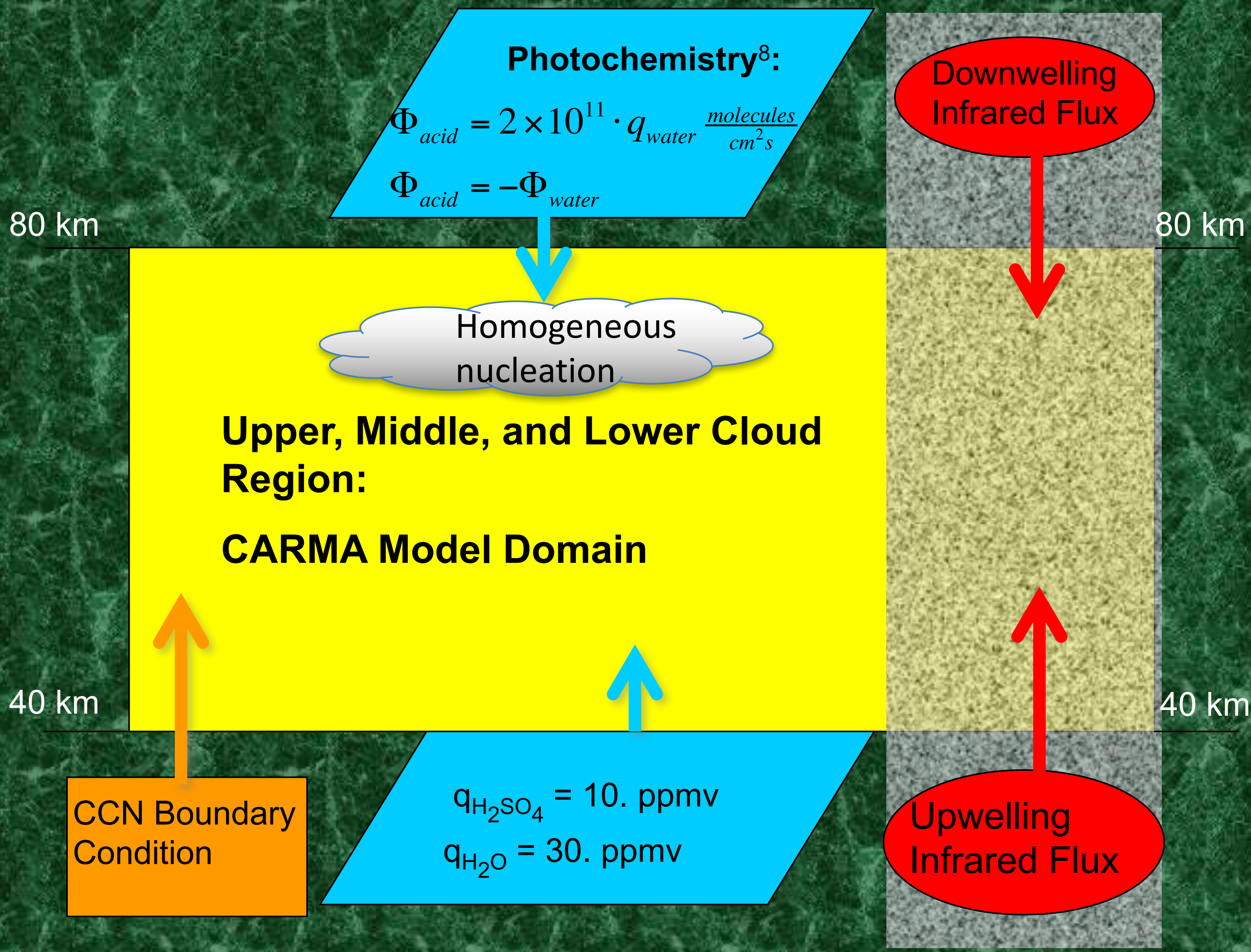
Financial Support: The Fujihara Foundation of Science (http://www.fujizai.or.jp/e_gaiyo.htm)

Contact: akatsuki-v2018inquiries@cps-jp.org
Registration will open in early 2018.
Please visit https://www.cps-jp.org/~akatsuki/venus2018/

The Venusian Cloud Decks

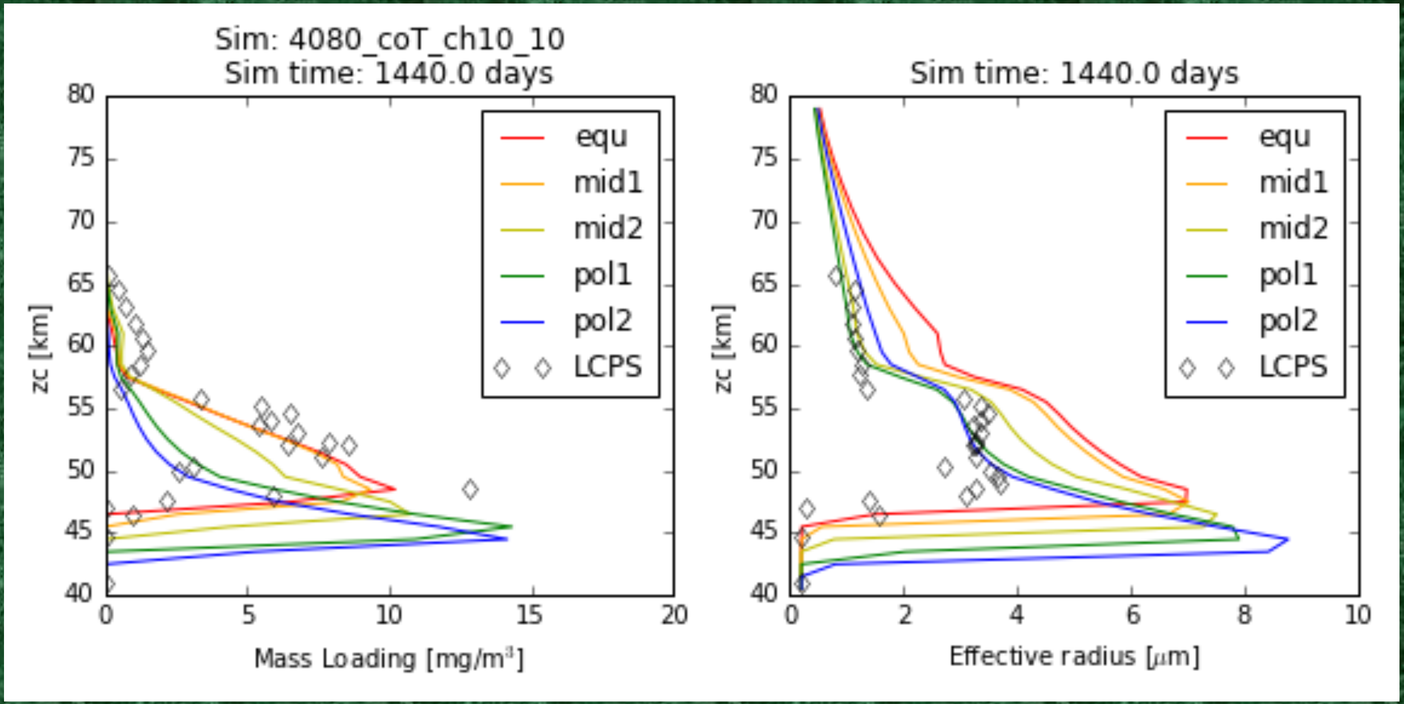


Microphysics, Chemistry, and Radiation cloud model



Results from Nominal Model

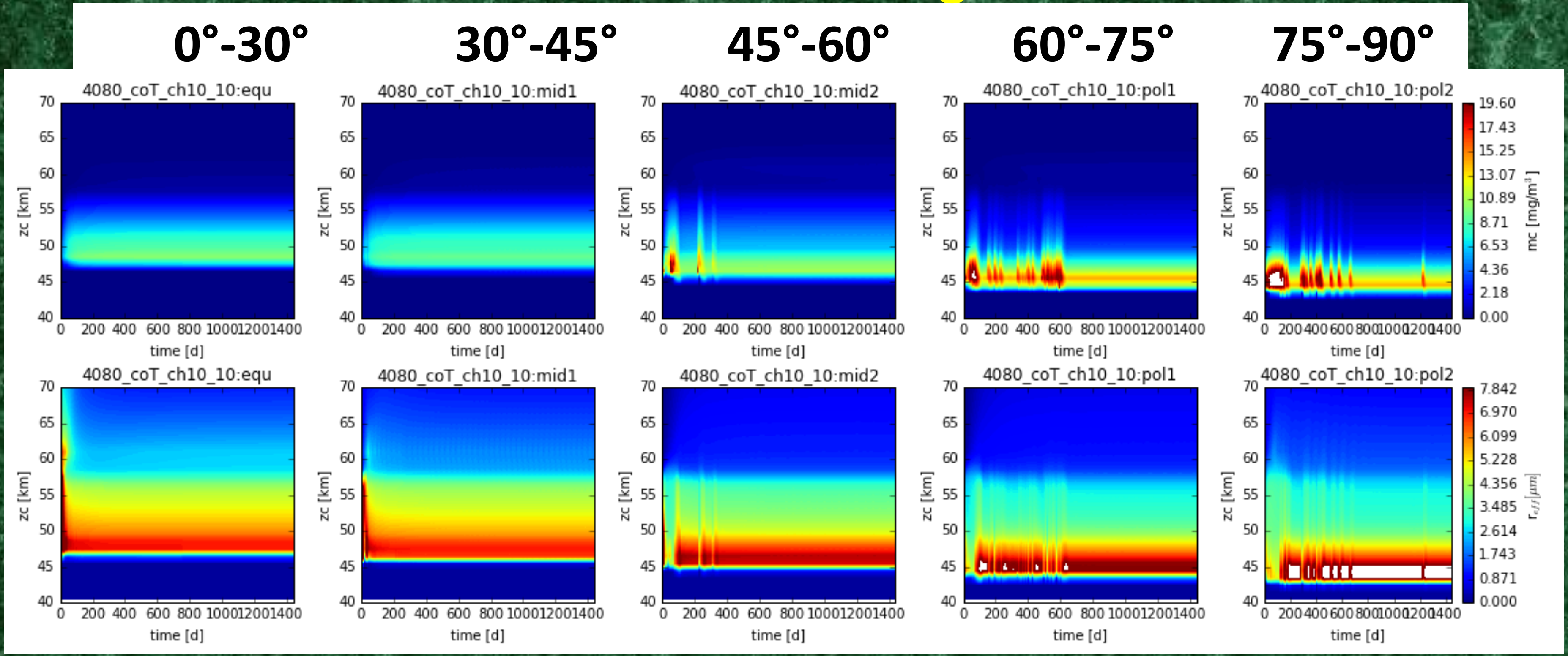
Mass Loading **Effective Radius**



- Condensational cloud appears similar to 40-60km domain case
- Though, polar profiles slightly better match to effective radius than before
- Mass of photochemical cloud is severely deficient
  - particle sizes are reasonable in the 45-75 degree latitude range).
  - But too large in the equatorial case: too efficient/focused acid prod?

4080_coT_ch10

Mass Loading



Effective Radius

- Fairly steady-state behavior; but very unstable at higher latitudes
- Possibly due to arbitrary forcing of photochemistry altitude at 60-62km
- Also, Particle sizes in upper cloud increase with time through first ~100days
    - Both mass loading and effective radius better match to data early on

Cloud size parameter comparison

- More consistent with observations when coalescence included
- Not a surprise, since coalescence is important in the lower clouds
- May have significant effect if applied to upper clouds only

Table 1: Size parameter: $I(1.74)/I(2.3)^{0.53}$

Latitude	No coalescence	With coalescence	Wilson et al. (est)
0-30	0.294	0.615	0.6
30-45	0.231	0.658	0.65
45-60	0.191	0.676	0.7
60-75	0.273	0.550	0.65
75-85	0.251	0.545	0.8

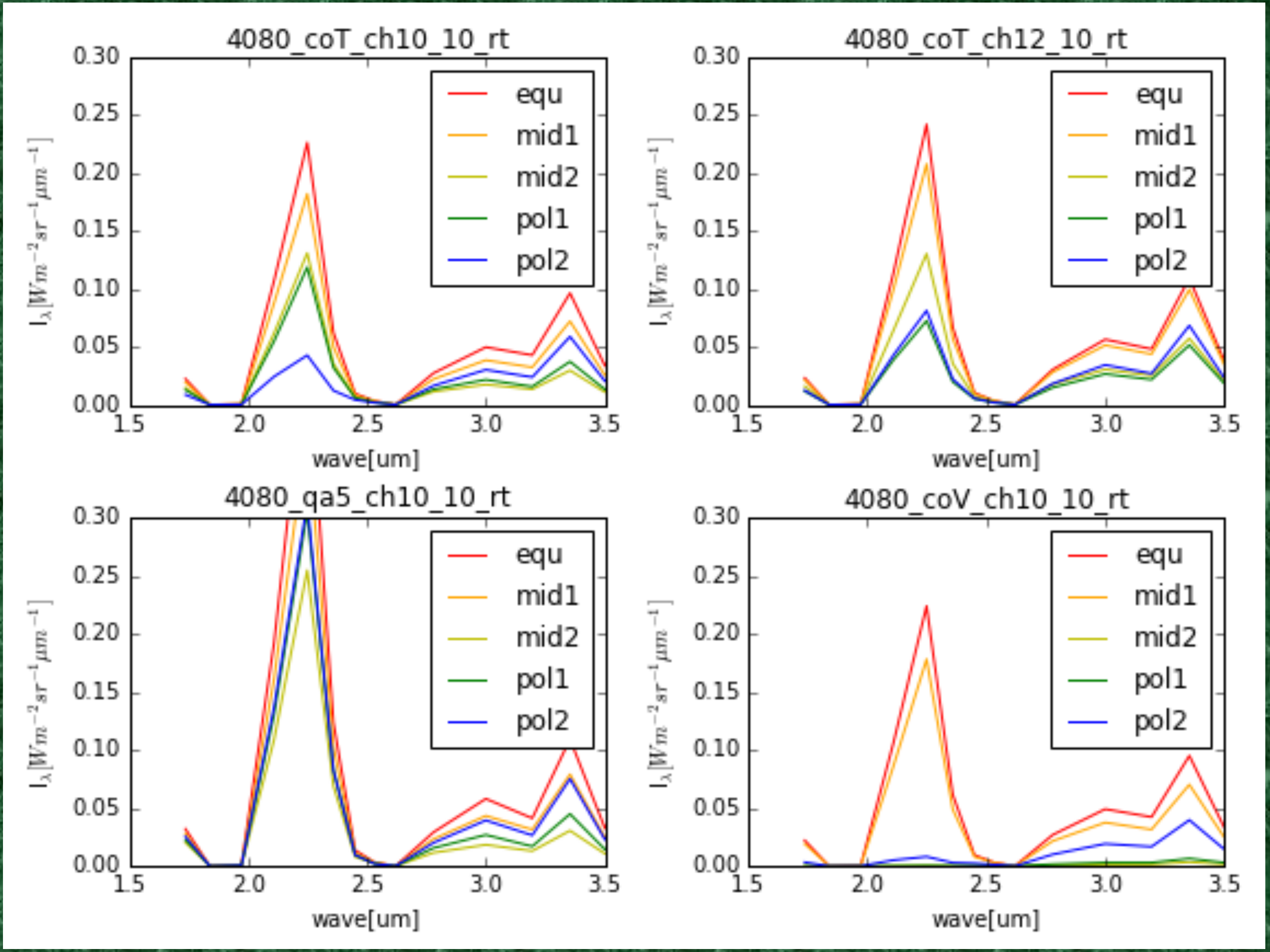
- This is future work.
- Using Akatsuki IR2 filter information, produce radiance and size parameter predictions for comparison
- Also, simulate smaller timescale phenomena.

Condensational Cloud Sims

Sim	Tau	I_173	I_230
coT	16.91	0.0129	0.0964
coF	17.57	0.0121	0.0861
qa5	13.15	0.0202	0.239
uc00	11.21 ± 0.956	0.0237 ± 0.00234	0.247 ± 0.0400

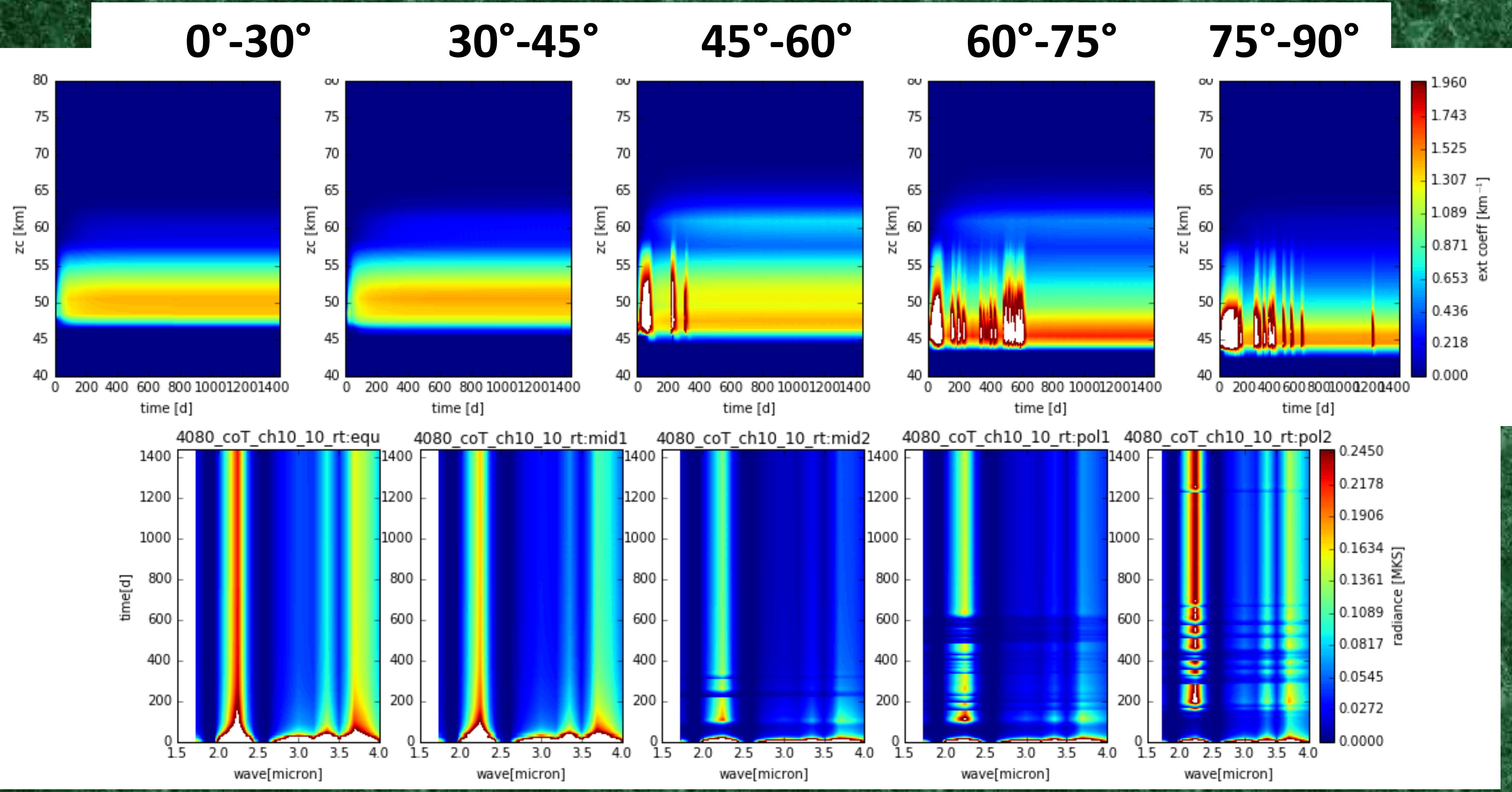
- Only the last two years in the statistics
- Standard Deviations not shown for sims in stable steady state
- Both reduction of acid vapor BC and reduction of upper cloud BC resulted in order of magnitude changes in 2.30 μm radiance
- But, recall, there is no upper cloud in these sims.

Near Infrared "Spectrum"



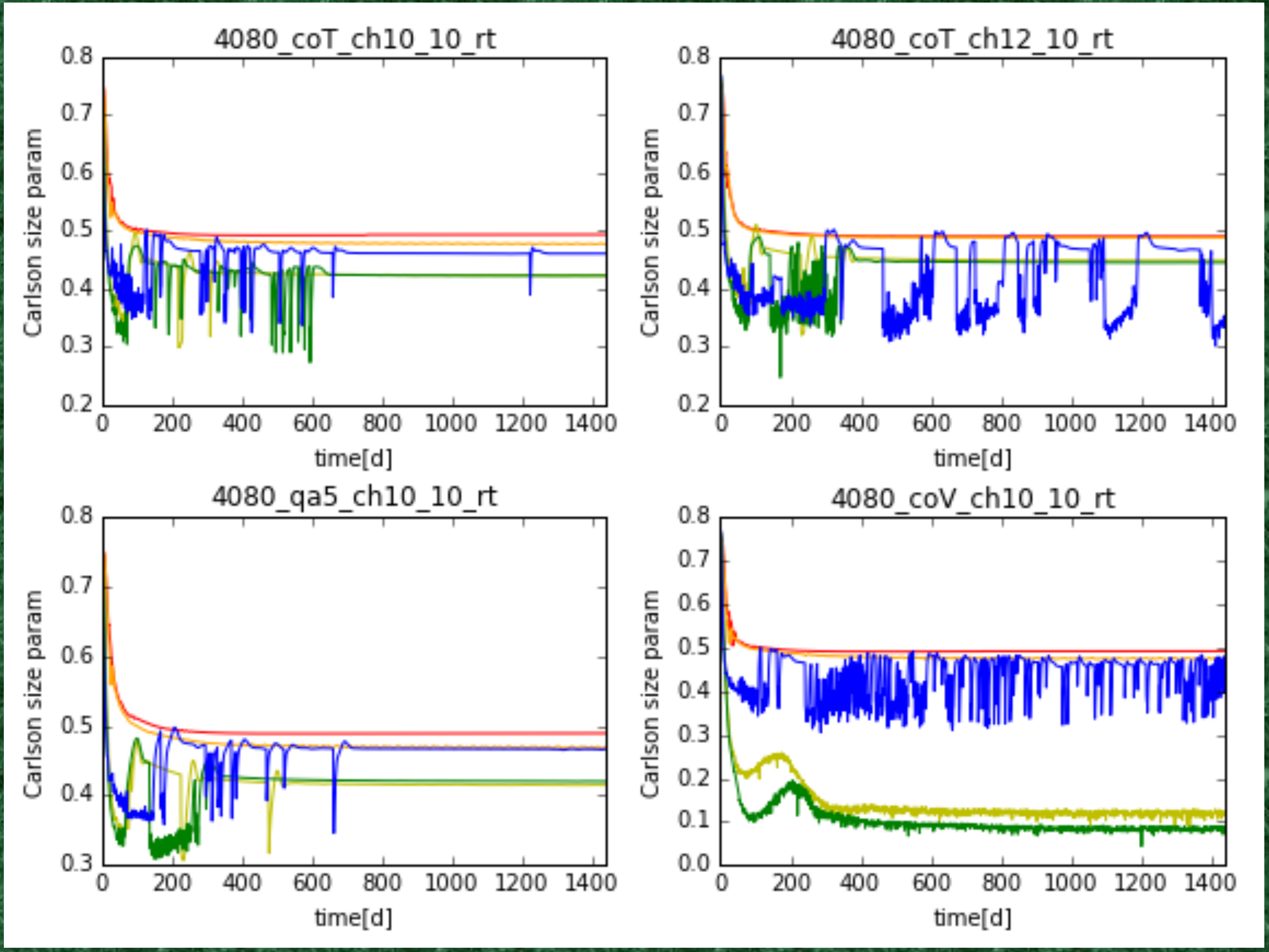
4080_coT_ch10

1.74 micron aerosol extinction coefficient



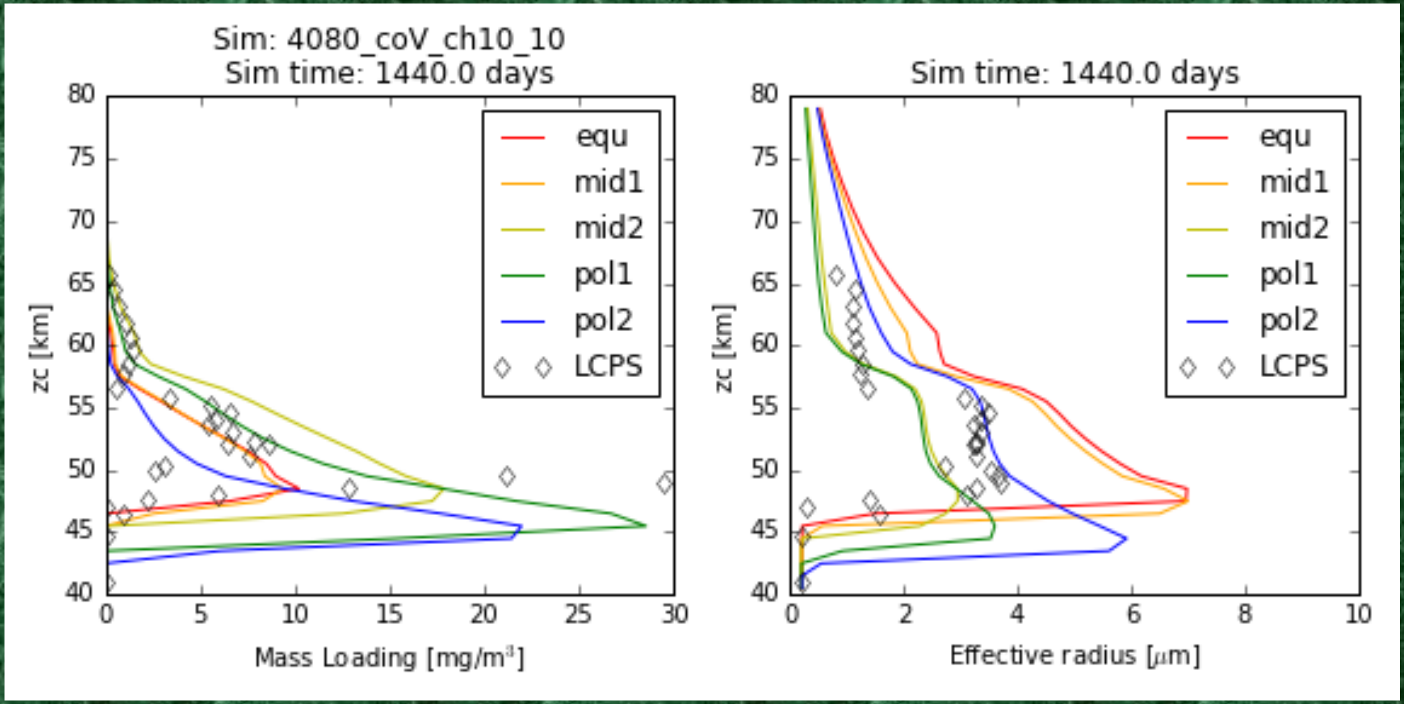
Near infrared radiance

Size Parameter with time



Temperature dependent Coagulation

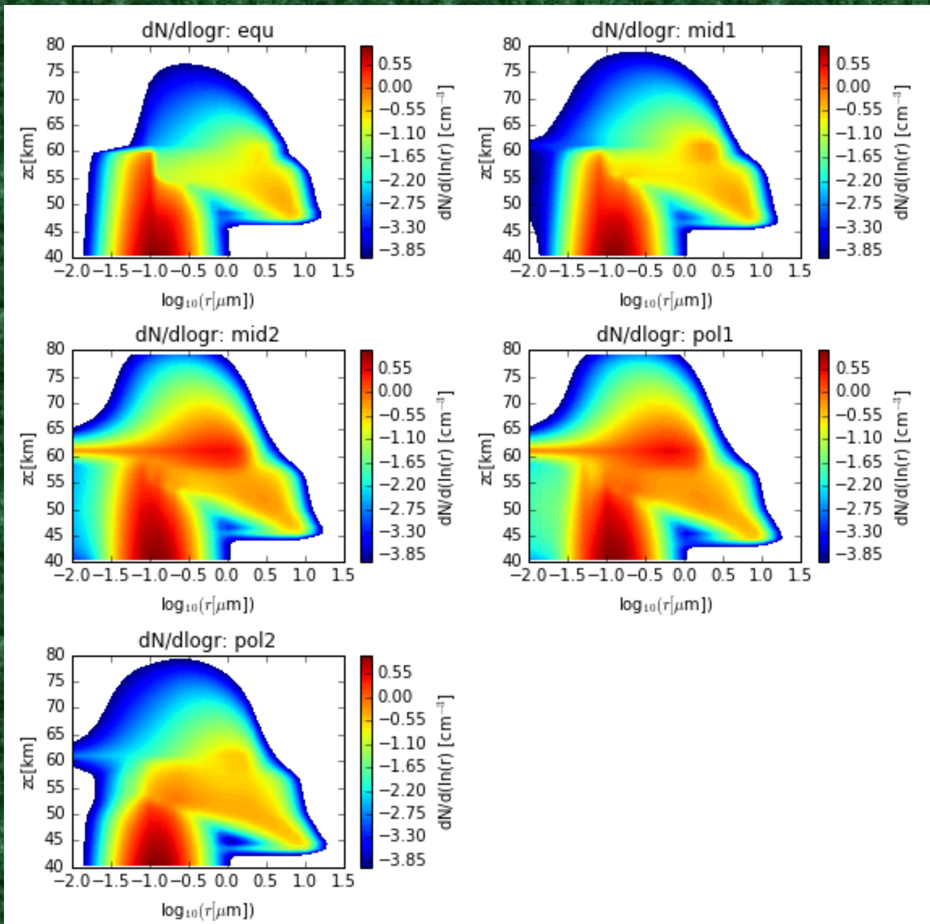
Mass Loading **Effective Radius**



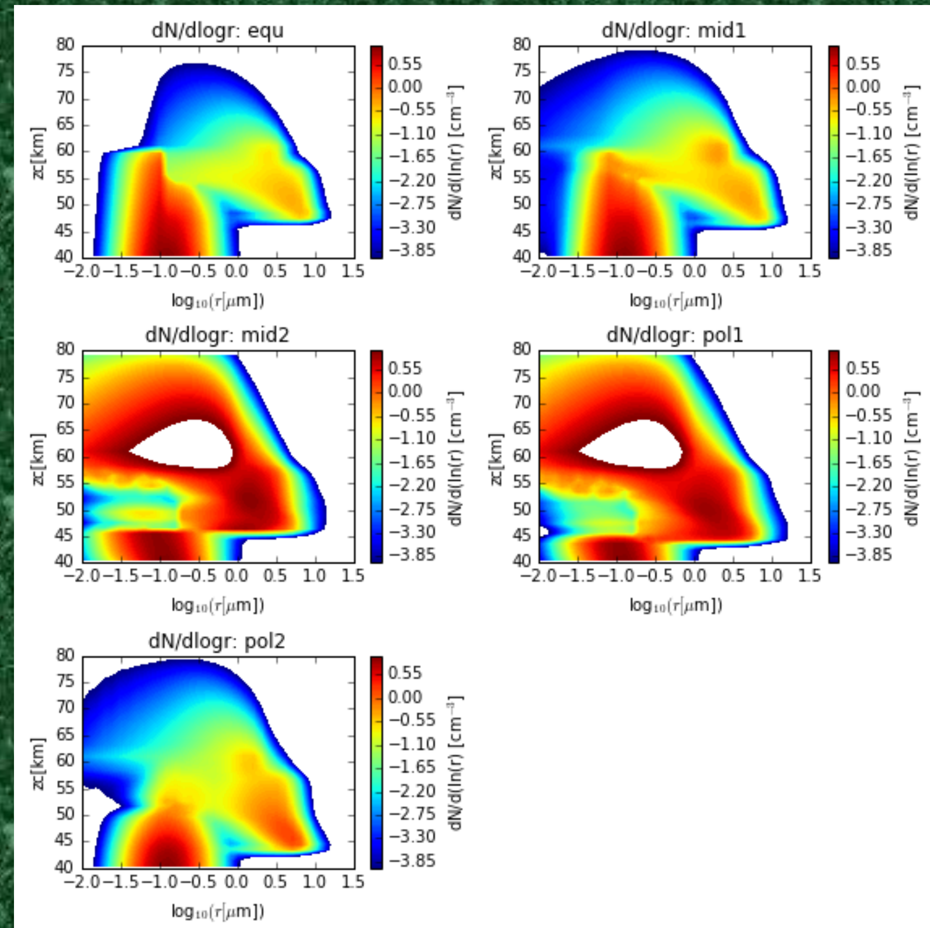
- Temperature-dependent coagulation permitted.
- Latitude trend no longer consistent with observations (temporal variation)
- Better match to photochemical cloud mass for mid latitudes.
  - Though, particle sizes a touch too small
- Polar profile very closely match particle sizes in the middle cloud
- Pol1 nearly reaches the LCPS peak in mass loading at cloud base.

40-80km simulation Size Comparisons

Nominal



Coag Var



- Three Modes clearly seen: CCN, photochemical droplet, condensational droplet
- Largest effects seen in the CCN population
  - Completely scavenged in mid2 and pol1 of coag Var
- Activation/Nucleation primary driver?

Full Cloud Simulations

Sim	Tau CC	Tau PC	I_173	I_230
4060 coT	16.91	---	0.0129	0.0964
4060 coF	17.57	---	0.0121	0.0861
4060 qa5	13.15	---	0.0202	0.239
4060 uc00	11.21 ± 0.956	---	0.0237 ± 0.00234	0.247 ± 0.0400
4080 coT	10.71 ± 7.86e-3	0.6157 ± 7.14e-5	0.0220 ± 1.92e-5	0.219 ± 5.55e-4
4080 coV	10.74 ± 6.56e-3	0.6681 ± 17.2e-5	0.219 ± 1.59e-5	0.217 ± 4.65e-4
4080 qa5	7.84 ± 1.65e-3	0.7094 ± 9.91e-5	0.0317 ± .980e-5	0.442 ± 3.73e-4
4080 ch12	10.61 ± 1.42e-3	0.6095 ± 33.6e-5	0.028 ± 1.02e-5	0.235 ± 2.01e-4

- Both reduction of acid vapor BC and reduction of upper cloud BC resulted in order of magnitude changes in 2.30 micron radiance
- NB, this is equatorial profile only; others exhibit much larger stdev

Conclusions

- First draft of RT model for direct comparison with Akatsuki IR2 is producing reasonable results
- Variable Coagulation has had a dramatic effect on the Simulated Venus cloud system
  - However, much of the observed changes can be attributed to variations in the CCN and activation or nucleation processes of droplet formation.
- RAPID changes are possible in the Venus clouds in response to such changes in particle formation.
- Next steps are to improve absorption coefficients and incorporate reflected sunlight calculations.